

CIVIL AERONAUTICS BOARD

AIRCRAFT ACCIDENT REPORT

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NORTHWEST AIRLINES, INC.,
LOCKHEED ELECTRA, L-188C, N 137US,
O'HARE INTERNATIONAL AIRPORT
CHICAGO, ILLINOIS, SEPTEMBER 17, 1961

SYNOPSIS

On September 17, 1961, at 0857 c.d.t., a Northwest Airlines, Inc., Lockheed Electra, N 137US, crashed shortly after takeoff from runway 14R, at O'Hare International Airport, Chicago, Illinois. All 32 passengers and the crew of 5 sustained fatal injuries. The aircraft was totally destroyed by impact and subsequent fire.

Flight 706 originated in Milwaukee, Wisconsin, and was a regularly scheduled flight from Milwaukee to Miami, Florida, with intermediate stops at Chicago, Illinois, Tampa, and Fort Lauderdale, Florida. While at O'Hare Airport the aircraft was routinely serviced and checked, and a scheduled crew change was made. At approximately 0855, while taxiing from the ramp, the flight was cleared for takeoff, and shortly thereafter the aircraft departed. Takeoff and initial climb appeared to be normal, but at approximately 200 feet a shallow turn to the right continued into a gradually increasing bank of about 85 to 90 degrees. While in the turn, the crew made a short, garbled transmission indicating alarm. During the latter part of the turn a gradual descent began and, two minutes after takeoff, the aircraft struck the ground.

The Board determines that the probable cause of this accident was a mechanical failure in the aileron primary control system due to an improper replacement of the aileron boost assembly, resulting in a loss of lateral control of the aircraft at an altitude too low to effect recovery.

Investigation

Aircraft N 137US, a Northwest Airlines Lockheed Electra, was operated as Flight 711 from Miami, Florida, to Milwaukee, Wisconsin, on September 16, 1961, the day before the accident. After a layover in Milwaukee, the same crew which operated N 137US on September 16 originated Flight 706 on the morning of September 17 and flew the aircraft to O'Hare International Airport. Flight 706 was a regularly scheduled operation from Milwaukee to Miami, with intermediate stops at Chicago, Illinois, Tampa, and Fort Lauderdale, Florida. While on the ground at O'Hare Airport the aircraft was given a turnaround check, routine servicing, and a walkaround inspection. A scheduled crew change was made, and the flight was dispatched with the gross weight and center of gravity within prescribed limits.

file

At approximately 0855^{1/}, the flight was cleared for takeoff on runway 14R. At this time the aircraft was taxiing on a westerly heading in the runup area adjacent to runway 14R. Flight 706 acknowledged the clearance, while continuing toward the runway, and made a running takeoff. No witnesses were found who observed the actual lift-off. N 137US was observed after lift-off, 3,000 to 4,000 feet down the runway at an estimated altitude of 50 to 75 feet and in a normal climb attitude.

At the 8,000-foot marker the altitude of the aircraft was estimated to have been approximately 100 feet, which is a slightly lower altitude than Electra aircraft normally attain at this point during takeoff. Five witnesses noted a change in engine sound during this portion of the flight. Between the 8,000 and the 9,000-foot runway marker the aircraft was observed to commence an apparently coordinated right turn with a slowly increasing rate of bank. When the bank angle was 30 to 45 degrees, the crew made a short, garbled transmission. Immediately thereafter, at a bank angle of 50 to 60 degrees, the aircraft began to lose altitude. The maximum altitude attained in the entire turn was 200 to 300 feet.

The right wing near the No. 4 engine struck powerlines adjacent to the Chicago Northwestern Railroad tracks, severing the lines at an angle of about 70 degrees from the horizontal, and causing a bright bluish flash. The aircraft then continued in a direction of about 271 degrees magnetic and, when in a bank of about 85 degrees and a nose-down attitude of about 10 degrees, the right wing of the aircraft struck the railroad embankment. Continuing to roll about its longitudinal axis, the aircraft cartwheeled, the nose crashing into the ground 380 feet beyond the point of first impact, and landed right side up. It then slid tail first another 820 feet. The aircraft disintegrated throughout its path, and wreckage was strewn over an area 200 feet wide and 1,200 feet long. Evidence of ground fire was found at various points along this path.

Impact occurred on airport property about 3,800 feet abeam and to the right of the end of runway 14R, about 500 feet north of Irving Park Road. After passing beyond the railroad embankment the aircraft was lost to view by most of the eye-witnesses because of trees and other obstructions; immediately thereafter a large mushroom of orange-red flame accompanied by heavy black smoke was seen. Time of impact was established as 0857. The aircraft was demolished by impact and fire. All occupants were fatally injured.

The weather at time of takeoff was: sky clear; visibility 6 miles; smoke and haze; wind south at 8 knots; temperature 59 degrees F; dewpoint 52 degrees F; altimeter 30.40.

Runway 14R is 11,600 feet long. Airport elevation is 667 feet m.s.l. The Chicago Northwestern Railroad tracks are adjacent to the southwest boundary of the airport. These tracks are on a fill of 40 percent slope, 20 feet above the general terrain toward the runway. Each of the two powerlines in front of the fill consists of three heavy wires carrying 38,000 volts.

Members of the crew which operated N 137US on its flights just prior to the accident testified that no operational problems were encountered and that no mechanical discrepancies were noted during these flights. The Northwest Airlines crew

^{1/} All times herein are Central Daylight based on the 24-hour clock.

chief who performed the turnaround check on N 137US after its arrival at O'Hare Airport, and who also accompanied the outgoing flight engineer during a walkaround inspection of the aircraft, testified that it was airworthy prior to its final flight. A review of company and Federal Aviation Agency records showed that all crew members involved were certificated and qualified to operate the Lockheed Electra. Dispatching of Flight 706 was found to have been normal and in accordance with company operating procedures.

Most witnesses indicated that the flaps were down to some degree at takeoff and that the landing gear was retracted after lift-off. All agreed that prior to impact with the powerlines there was no fire or smoke seen. Nothing was observed to separate or fall from the aircraft, no birds were seen in the flightpath, and no abrupt pullup or violent maneuver prior to the steep bank was observed.

To assist in developing a flight profile based on actual operation of Electra aircraft, tower personnel, at the request of Board investigators, conducted a survey of 44 Electra takeoffs. These takeoffs were sampled at random and were all observed when using runway 14R. The survey disclosed that the average lift-off was made when these aircraft were approximately 4,000 feet down the runway, and that when they reached the 8,000-foot marker, their altitude and airspeed indications were about 280 feet and 158 knots respectively. The airspeed was based on 28 pilot reports given to the tower. In addition, Lockheed Aircraft Corporation, in response to the Board's request, provided a study of the flightpath based both on L-188 performance data and information disclosed during the investigation. Their study encompassed a ground envelope of reported flightpaths but, based on performance data, the inner boundary was considered as the only possible flightpath. Based on the Lockheed study, Board investigators prepared the estimated flightpath chart. See Attachment #1.

Parts of the flight recorder were found strewn along the entire wreckage path. Due to the forward location of the recorder in the fuselage, high impact loads had cracked and sheared the cast stainless steel magazine and fragmented the record foil contained therein. That part of the foil bearing the record of the final takeoff was not recovered, with the result that no useful information was obtained from the recorder.

Following acknowledgement of takeoff instructions, no further radio transmissions were made by the crew until the aircraft had gone into a steep bank of 30 to 45 degrees. At this time the crew transmitted its last message. The transmission was seven seconds long, delivered rapidly in a high-pitched voice, and was poor in signal quality. The control tower recording of this communication was studied by the Bell Telephone Laboratories and the Dictaphone Corporation. As closely as could be determined it was, "we're in trouble (break) uh and all units holding this is Northwest alert. I still don't have release right turn in no control (intake of breath) (garbled phrase)." The first two words of the garbled phrase may have been "can you?" or "have you?" The garbled phrase was higher in pitch and more rapid than the preceding utterances.

All four engines and propellers had separated from the aircraft and were found along the wreckage path. Fuel and oil samples taken from refueling servicing units which had serviced the aircraft, and from the aircraft prior to takeoff, showed that the proper specifications for engine and propeller operation had been met. The powerplant accessories were examined and bench-tested where possible, but no evidence of operational distress was noted. There was no evidence of operational

distress in the lubrication and scavange systems of any engine, and the compressor and turbine bearings were adequately lubricated. All fuel pumps were in good condition. Complete powerplant disassembly, as well as propeller slashes along the ground, revealed that the engines were all rotating at impact. The readings obtained from torquemeter, turbine inlet temperature, and phase detector indicators were unreliable in definitely establishing engine power, as they did not correlate with each other or with the propeller blade angles at impact. However, these readings did confirm that the engines were operating. The propeller blade angle for all propellers was in a range compatible with the flight idle position, and was the most reliable indication of the operating characteristics of the engines at impact.

Investigation of that part of the electrical system which remained after impact and subsequent fire revealed no indication of loss of electrical power during flight. Examination of the rudder, elevator, and wing flap systems showed no signs of failure or malfunctions, and that upon impact the flaps were in takeoff position, elevator trim tab set at 10 degrees noseup, and rudder tab at zero degrees. Actual position of the aileron trim tab could not be determined, but the aileron trim cockpit control was positioned at zero degrees. All landing gear was in the retracted position.

Some of the flight instruments were recovered but most were damaged to such an extent that no useful information could be determined. One instrument, the captain's artificial horizon, indicated that it was receiving a signal of 90 to 100 degrees right bank at the time it ceased to function.

Although it could not be definitely determined whether the autopilot engagement switch was on or off, several arced leads were found in the autopilot circuitry indicating the presence of electrical energy at impact. However, the autopilot engagement pistons in all three control surface booster units were found in the "off" position. The autopilot was placarded "inoperative" by the carrier pending performance of a required modification.

The rudder and elevator boost units were found in the "engaged" position; the aileron boost unit was found in the "disengaged" position. However, because of the possibility of cables pulled due to break-up forces, it could not be determined to what position the boost unit controls had been actuated by the crew prior to impact. The aileron boost unit which had received external fire and over-all impact damage was given a complete disassembly and inspection at the Lockheed Aircraft Corporation, Burbank, California, under Board supervision. Measurements of the actuating piston, which had seized in the cylinder due to fire damage, represented a flight control movement of right wing down. After replacement of all fire damaged "O" rings, seals, and the cylinder, the unit was reassembled from the remaining original parts and operated in a satisfactory manner. The rudder and elevator boost units, which were not so extensively damaged, were also functionally tested and found capable of normal operation. No evidence was found in any of the boost units to indicate that a malfunction had occurred prior to impact. Hydraulic fluid samples taken from the boost units did not reveal any significant findings.

Components of the aileron primary control system, from the aileron boost unit to the ailerons, were damaged and broken in numerous places. Nevertheless, examination

2/The relatively slow, progressive disintegration which occurred in this accident makes it impossible to assess the in-flight significance of instrument readings which might otherwise be reliable.

of this part of the aileron primary control system disclosed no evidence of any malfunction or failure prior to impact. However, impact marks made on the inboard closing rib of the right aileron indicated that the right aileron was deflected upward three degrees, corresponding to a flight control position of right wing down.

From the aileron boost unit's input quadrant to both control wheels, the aileron primary control system consists of two cables which run through a series of pulleys to the control wheels, forming a closed loop.^{3/} The cable which connects to the pilot's control horn is in tension for a right wing down control movement and the cable which connects to the copilot's control horn is in tension for a left wing down movement.^{4/} These cables provide a signal input from the control wheels to the boost unit when the boost is engaged, and they also provide the physical link between the control wheels and the ailerons for manual operation when the boost is disengaged.

The pilot's cable run starts with a 153.53-inch run of flexible cable routed athwartship to a pulley at Butt Line 34R, Water Line 128.5. From here, the cable consists of two consecutive 205-inch lengths of lockclad cables which run aft and down to a point just in front of a pulley bracket at Fuselage Station No. 651. A 39.25-inch flexible cable then joins the lockclad and passes through a 0.6-inch diameter guide hole in the front of the pulley bracket at Fuselage Station No. 651 and connects by a left-hand threaded stainless steel connector 4.2 inches long into the forward brass terminal block of a slack absorber unit. Proceeding from the aft brass terminal block of the slack absorber is a stainless steel, right-hand threaded connector attaching to a 42.01-inch length of flexible cable with a swaged ball fitting at the end which connects on the aileron boost input quadrant.

The copilot's cable is routed athwartship with a 200.34-inch length of flexible cable to a pulley at Butt Line 16.7L and then returned to the right side to a pulley at Butt Line 35R, Fuselage Station No. 127, and Water Line 132. From here aft, the run consists of lockclad cables identical with and parallel to the pilot's cable, and approximately an inch outboard. Just in front of the pulley bracket at Fuselage Station No. 651, a 43.75-inch flexible cable connects to the lockclad and passes through a 0.6-inch diameter guide hole in the front of the pulley bracket approximately one inch to the right and one-half inch below the pilot's flexible cable guide hole. After this, it joins a slack absorber unit with identical stainless steel fittings as on the pilot's side except that the forward one is right-hand threaded, and the rear, left-hand threaded. A 28.88-inch flexible cable with a swaged ball on the end connects the cable to the aileron boost input quadrant.

The position of the copilot's control wheel at impact could not be determined, but the pilot's control wheel broke in a forward direction and was positioned about 90 degrees to the left, calling for almost full left wing down.

Between the pilot's control column horn and the aileron boost input quadrant, all recovered cable connections were found to be normal except for the threaded connector of the slack absorber forward terminal block. This connector was found unsafetied and was backed out of the terminal block, showing five to seven threads

^{3/} A schematic diagram of this part of the aileron primary control system is shown in Attachment #2.

^{4/} These cables will hereinafter be referred to as the pilot's and copilot's cables, or as right wing down and left wing down cables, respectively.

for a 0.40-to 0.45-inch engagement.^{5/} This slack absorber unit, minus its aluminum side plates, is shown in Attachment #3. The forward connector (shown on the right in Attachment #3) should be safetied with steel wire exactly like the aft connector (on the left in Attachment #3). Distinctive lines on the surface of the slack absorber's aft connector showed where safety wire had shielded these surfaces from fire and soot. In contrast, no such distinctive lines could be found on the forward connector in question. Laboratory examination by the National Bureau of Standards and the Federal Bureau of Investigation revealed no evidence of safety wire having been recently installed on this connector.

The copilot's slack absorber unit, the flexible cables on either end of it, and the rear section of the two 205-inch runs of lockclad cable were never recovered from the wreckage. Indentations were found about the guide hole of the still-intact Fuselage Station No. 651 pulley bracket. This guide hole, through which the copilot's 43.75-inch length of flexible cable passes, is 0.6-inch in diameter. The slack absorber terminal block is too large to pass through the guide hole in a forward direction, and the lockclad collar is too large to pass through the guide hole in an aft direction. These indentations about the guide hole indicate that some object passed through it in a forward direction.

In order to explore the possibility that wing flap interference with the aileron control surface may have been a cause of the accident, the Board requested Lockheed Aircraft Corporation to perform certain ground tests. With Board investigators participating, tests were conducted to measure the amount of interference between flaps and aileron (with simulated airloads applied to the flap, and the outboard flap jackscrew removed), and to determine the amount of pilot force required to overcome such interference with aileron boost both engaged and disengaged. With boost engaged it was found that the exertion to overcome the interference was similar to normal deflections. With boost disengaged, a force of about 550 inch-pounds, applied and measured at the control wheel, was required to force the aileron past the flaps. The force required was well within the capability of a pilot to exert.

Lockheed Aircraft Corporation performed another ground test, the results of which were made a part of the investigation. Because of a suspected failure in the system, this test was made to determine the ultimate load required to fail a portion of the aileron boost input cable system. Loads were applied to the aileron primary control system and increased progressively to 2,000 pounds, at which time the flexible cable itself failed in tension at a point between the pulley bracket assembly and the slack absorber. Examination revealed no failures, thread stripping or deformations of associated cable assembly brackets, pulleys, connectors, etc.

It has long been accepted that a flexible cable, as used in the aileron primary control system, has a tendency to unscrew from a connector. The National Bureau of Standards, in 1941, conducted tests which showed not only that a cable would unscrew from a connector, but that it could exert enough torsional force to actually break the soft brass, cadmium-plated safety wire then in use by the aircraft industry. After breaking the safety wire, the connector would spin free of the turnbuckle. Nevertheless, in order to verify the existence or non-existence of this tendency in the L-188 aileron primary control system, the Lockheed Aircraft Corporation conducted certain tests, the results of which were also received into evidence. Using cable and slack absorber parts identical to those installed in the copilot's side of the system, with vibration applied to simulate flight conditions, and without safety wire

^{5/} The slack absorber is normally installed as a turnbuckle with both connectors engaged equally to a depth of 1.2 to 1.55 inches with no threads showing. Cables in the system are rigged to 125 (\pm 5) pounds tension at 70 degrees F.

installed, it was demonstrated that the cable had a natural tendency to, and did, unscrew from its fitting.

Still another ground test performed at Lockheed Aircraft Corporation and witnessed by Board investigators was one which simulated failure of the left wing down aileron cable in an Electra aircraft. With hydraulic pressure applied, boost engaged, and ailerons in neutral, the cable, identical to the aileron cable missing from the wreckage of N 137US, was severed with a pair of cutters. The person holding the control wheel felt only a slight pulse when the cable was cut and was not otherwise aware of what had occurred. When the cable severed, an immediate signal was imparted to the boost input calling for right wing down. Measurements showed that the trailing edge of the aileron had moved six inches above its normally faired position. When the control wheel was then moved to the left wing down position, the slack in the left wing down cable caused the cable connectors to hang up on aircraft structure.

A review of the manufacturer's records showed that N 137US was manufactured June 14, 1960, that the Lockheed Electra Action Program, a major structural modification, was completed January 31, 1961, and that its final acceptance flight was performed June 21, 1961. On June 22, 1961, the airplane was delivered without discrepancies to Northwest Airlines, Inc., and was placed into service on the same date.

From June 27 to July 11, 1961, eight aileron control discrepancies were entered in the aircraft logs of N 137US. Most of these discrepancies reported: sluggish feel in aileron boost; delayed reaction in aileron boost, sticking or binding of aileron boost, boost pulses in aileron controls at all speeds; ailerons erratic at all speeds. Although two pilot writeups indicated the need for an in-flight check, examination of the records failed to disclose that an in-flight maintenance check was made. In one instance the pilot entered the remark ". . . OK on ground"; the corrective action entered in the log was, "checked aileron linkages & surfaces for clearance with flaps extended & found O.K. for further observation." In the other instance the pilot writeup was ". . . unable to feel on the ground - only inflight condition"; the corrective action shown in the log was, "checked ail. sys. & boost package OK for further observation." Most of the corrective actions recorded indicated the performance of ground checks; one entry showed replacement of the boost valve and hydraulic filters; but one log carried only the barren entry, "noted." During this period of time the aircraft continued to be dispatched on a total of 29 flights.

On July 11, 1961, the aircraft was placed in the Northwest Airlines maintenance facility at Minneapolis, Minnesota, to undergo a layover check. Since the aileron control difficulty was still manifesting itself, it was decided to also replace the aileron boost assembly. Concerning the latter task, the then current company maintenance policies required that the Lockheed Electra maintenance manual, which prescribed the steps for the removal and replacement of the aileron boost assembly, be followed by those performing the work.

A Northwest Airlines maintenance manual required that red Unit Inoperative Tags, Forms OM-249, be attached to pertinent cockpit controls. The purpose of this requirement was to prevent operation of controls when such action is undesirable or dangerous during the performance of various maintenance operations, and to prevent release of an aircraft for dispatch when uncompleted work remains in an inconspicuous place. This directive also prescribed that upon completion of the task,

provided it has been satisfactorily performed, an inspector will sign the tag and remove it from the aircraft. A quotation from this directive emphatically stated "under NO circumstances shall the tags be removed from the aircraft before they are properly signed by an Inspector." The directive further required that a record of the use of the red Unit Inoperative Tag be transcribed to a more permanent type of work control card to which the red tag must be stapled.

A separate section of the carrier's maintenance manual, specifically highlighting the possibility of incomplete work overlapping a shift change, required the use of the Unit Inoperative Tag when removing safety wire from turnbuckles in all control cable systems.

An interoffice memorandum dated June 21, 1957, signed by the Chief Mechanic and the Senior Supervising Inspector, constituted an important company policy in effect during July 1961. Paragraph 1A of this memorandum required that when a flight control is changed or removed and reinstalled on a "service" check, an inspector follow up on the installation and sign for it in the log book. Because an aileron boost assembly is a major component of a flight control, it is evident that this paragraph governed followup responsibility for the aileron boost unit change in question. However, paragraph 1D of the memorandum stated that, at the request of the Foreman or Crew Chief, the Inspector will inspect any unit replacement and sign for the inspection in the log book, and that the Foreman will be responsible for advising the Lead Inspector of any major units, not called out in paragraph 1A, which should be followed up by Inspection. Most of the Northwest Airlines line maintenance and inspection officials who testified, indicated that the requirements of paragraph 1D constituted the governing policy which should have been followed during the aileron boost unit change on N 137US. Testimony at the public hearing further disclosed that in actual practice mechanics were also permitted to call for an inspection.

This particular aileron boost unit change on N 137US was the first such job to be performed on an Electra aircraft by the carrier's line maintenance personnel principally involved. The foreman who supervised the unit removal testified that he believed this was the first boost package change in which line maintenance was involved. During July 1961, three shifts were operated throughout each 24-hour period. Shift 1, from 6 30 a.m. until 2.30 p.m.; Shift 2, 2 30 p.m. until 10:30 p.m.; and Shift 3, from 10 30 p.m. until 6:30 a.m.

Removal of the malfunctioning aileron boost unit was accomplished by two mechanics of Shift 2 on the night of July 11. One mechanic was occupied with other aircraft during most of the shift and worked on the unit removal only during his spare time; the other mechanic performed most of the removal work. Both testified that they followed the manual prescribing the steps to be followed in removing the unit. However, upon further questioning, the mechanic who did most of the work admitted that he did not follow the manual exactly step by step. In accomplishing his task he removed the safety wires from the connectors at the forward ends of the pilot's and copilot's slack absorber units and unscrewed them to relieve cable tension, thereby facilitating the removal of the boost unit. This was done in accordance with the instructions contained in the Lockheed Electra maintenance manual. One mechanic stated that he definitely recalled having seen red Unit Inoperative Tags fastened around the control column and on the hydraulic pump switch, but neither mechanic remembered who had installed these tags. No inspectors were called to inspect the disassembly work as no inspection was necessary at this stage of the work. By the end of Shift 2 the aileron boost unit had been completely removed from the aircraft and placed on the floor of the hangar. That any information concerning

the removal of safety wires and loosening of cable tension was passed on to the succeeding shift could not be conclusively determined from these two mechanics.

Installation of the new aileron boost unit was performed by two mechanics on Shift 3 during the night of July 11-12. Testimony established that neither mechanic had followed the manual step by step, referring to it only when a problem was encountered, and that neither had read the removal instructions to determine what components had been unsafetied, disconnected, or rendered inoperative in the removal of the boost unit. Step (10) of the Lockheed maintenance manual removal instructions states "Loosen turnbuckles at cable slack absorbers near aileron booster assembly in aileron input control cable runs to provide enough slack in cables to permit removing input quadrant. Access to turnbuckles is at Station 654-673 through floor opening." When asked if they had read this part of the manual, they both answered in the negative. Both were also asked if they had read and complied with step (19) of the Lockheed reinstallation instructions which states, "Rig aileron input control cable system, aileron boost shift cable system, and aileron emergency cylinder disconnect cable. Refer to 27-2-0 and 27-5-12 (AA only) for rigging procedures." They both testified that they had not. As a result, neither of the two mechanics tightened the cable tension which had been slackened during removal, nor did they replace any safety wires which had been removed during the previous shift.

Although both mechanics testified that they checked each other's work after completion of the installation, neither one could recall having made a specific check to insure that the previously loosened cable connectors were properly threaded into the slack absorber terminal blocks, the cable tension checked, or the connectors resafetied.

The mechanics did not call for an inspector to check the installation at any stage of their work, and they could not remember having seen an inspector performing an inspection of the unit installation during their shift. After completing the installation and performing an operational check of the unit, both mechanics signed off the aileron boost assembly change as completed in the aircraft log. Neither mechanic could recall having removed any red Unit Inoperative Tags from the aircraft. Their crew chief, who also had not read the manual for this job, then made a cursory inspection of the work, performed an additional operational check of the controls and signed off the job as completed in the aircraft log. Although the crew chief believed that he had done so, he could not positively recall having requested an inspector to inspect the installation, and he could not remember having seen or removed any Unit Inoperative Tags. Testimony of the two mechanics and their chief indicated that the unit change was completed near the end of their shift and that they did not pass any information concerning the unit change to the next shift (Shift 1).

The Shift 2 Foreman testified that he went to the aircraft twice to check on the progress of the aileron boost removal, but that he did not actually check the work itself. He could not recall having directed the use of the manual in the removal task. He could not say whether or not red inoperative tags were used on the job as required. During the shift he called the lead inspector to check the taper pin on the input bellcrank of the new boost unit, which had been drawn from stock, and then sent the unit to the hydraulic shop for a change of taper pin. At shift change the Shift 2 Foreman verbally informed the Shift 3 Foreman about the completion of the unit removal and the taper pin change. The Shift 2 Crew Chief, who assigned the mechanics to the removal task, testified that he was told that red tags were used, but that he did not so direct or personally ascertain their use; that from his

observation of the mechanics' work the manual was closely followed; that he did not observe the entire removal operation, and that much of his time was occupied with work on other aircraft.

The Shift 3 Foreman testified that he supervised the unit installation through the crew chief, visiting the aircraft three or four times to discuss such problems as were encountered but that at no time did he enter the cockpit, cabin or center section to check on the work itself. He did not recall seeing any red tags. Because the crew chief is authorized to do so, the foreman stated that he did not call for an inspector and did not order the crew chief to do so. He stated that at the end of the shift the aircraft was ready, and that the following shift was informed as to its availability for test flight.

The aileron boost change for N 137US was entered in the Inspection Activity Reports for both Shifts 2 and 3, but none of the inspectors of these shifts made any effort to determine if and when an inspection would be due. The Shift 1 Inspection Activity Report no longer carried the boost change entry, even though there were no entries on the previous Inspection Activity Reports indicating that the work had been inspected. No evidence was found to indicate that the status of the work was passed on to any Shift 1 Inspector. Although the Shift 1 Lead Inspector noted the entries concerning the aileron boost change on the previous shifts' Inspection Activity Reports, he could give no satisfactory explanation as to why he did not carry the entry over into his own shift activity report, nor could he positively recall having discussed the matter with anyone. All inspection personnel involved indicated that they had placed entire reliance upon the company policy which required line maintenance personnel to notify the Inspection Department of the need to inspect the aileron boost installation. The evidence shows that inspectors were never called, that inspectors did not on their own initiative investigate the status of the job, and that they did not make such an inspection.

On the morning of July 12 when Shift 1 reported for work, N 137US was rolled out of the hangar and prepared for a test flight. The aircraft log at this time reflected the following entries: the aileron booster assembly change signed off by the two Shift 3 mechanics and their crew chief, a layover check completed, a preflight completed, and past log entries examined. An inspector's signature did not appear on any part of the log. After reviewing the log, the Shift 1 Crew Chief then signed the "Released for Flight" block. He testified that when reviewing the log entries he assumed that the aileron boost change had been properly signed off and inspected. He also stated that the red tags had been removed from the cockpit and the pink cards, which serve as a permanent record of the use of the red tags, were on a desk near the front of the airplane. Although a search of aircraft records was made, no evidence of the use of those tags was ever found. The Shift 1 Crew Chief could not satisfactorily explain why he had released the aircraft for flight without the appearance of an inspector's signature opposite the aileron boost change entry on the log sheet.

The aircraft was flown on a test flight on July 12, 1961. After the test flight, a minor discrepancy concerning the aileron boost disconnect indicating light was entered in the aircraft log, but was signed off as satisfactory. No subsequent aileron system discrepancies appeared in the aircraft logs of N 137US.

Testimony received at the public hearing indicated that formal training of personnel in the maintenance of Lockheed Electra aircraft had been sporadic and that

no training had been given in flight control systems. Formal training of the two mechanics who removed the aileron boost assembly consisted of three days of air conditioning for one, and five days of powerplants and propellers for the other. One of the two mechanics who installed the new boost unit had not received any formal training. Although an active on-the-job training program existed, with designated instructor personnel available for consultation concerning unfamiliar tasks, this program was not utilized during the aileron boost unit change despite the fact that this was the first time any of the Northwest personnel involved had ever performed such an operation.

Analysis and Conclusions

It was determined that the flight was properly dispatched, the flight crew was qualified, takeoff gross weight and center of gravity were within prescribed limits, and weather was not a factor.

The change in engine sounds heard by several witnesses during a portion of the flight is attributed to an intentional and routine power reduction following lift-off. Examination of the powerplants disclosed that all four engines were capable of normal operation at impact. The most reliable evidence which indicated the operating characteristics of the engines at impact was that the blade angles for all propellers were in a range compatible with flight idle. It appears reasonable to assume that the pilot, upon realizing that a crash was imminent, abruptly reduced power shortly before impact.

The possibility of flaps interfering with the ailerons was investigated as a possible causative factor. However, tests proved that physical interference between the flaps and the ailerons could have been overcome by pilot control forces. Investigative findings also indicated that the rudder, elevator, and aileron trim tabs were positioned at their proper settings at impact. It is therefore believed that none of these factors contributed to the cause of the accident.

The investigation disclosed that there was electrical power on the Priority "A" bus at impact. It was further found that the electrical load had been transferred from the No. 3 to the No. 4 alternator, the standby alternator which was carrying the load for this bus. The reason for such a transfer could not be determined. However, numerous indications were found that electrical power was available in both "A" and "B" busses up to the time of impact. Therefore, it is reasonable to conclude that a loss of electrical power was not a causative factor in this accident.

Electrical energy was present in certain electrical circuits within the autopilot at impact, showing that this equipment was energized at the time. Although the autopilot switch was placarded as "inoperative," it was not guarded and could have been inadvertently turned on. If turned on, the reaction of the aircraft would have been governed by the setting of the autopilot indices at the time of turn on. However, since the autopilot can be easily overpowered or readily turned off by the pilot, it is unrealistic to believe that accidental or intentional actuation of the autopilot switch contributed to the accident. It is also possible that the autopilot circuitry became energized during the initial stages of the aircraft's breakup.

Examination of the rudder, elevator, and aileron boost units disclosed that each of these units was capable of normal operation at impact. The rudder and elevator boost units were recovered with the disengage mechanism in the boost-engaged position, but the aileron boost unit was found in the boost-disengage position.

Although this condition could have resulted from aircraft breakup forces, it does not appear probable, and the Board concludes that the aileron boost was disengaged by the crew at some time prior to impact.

Hydraulic power was used to retract the landing gear, and electrical energy to sustain hydraulic power was available up to impact. The fact that the rudder and elevator boost units were engaged and the aileron boost unit was disengaged, indicates that hydraulic pressure was available to operate all flight control boost units, and that the crew was not experiencing difficulty with either the rudder or elevator controls. However, these facts do indicate that the crew was having some type of aileron control difficulty and had disengaged the aileron boost unit in an attempt to solve the problem.

Shortly after takeoff the aircraft developed a rolling moment to the right which could not be controlled by the crew. Although the part of the crew's last transmission which stated, "I still don't have release right turn in no control" was uttered without a break, the Board believes that the first part, "I still don't have release" indicates an unsuccessful attempt by the crew to control the rolling moment manually by disconnecting the aileron boost, and that the second portion, "right turn in no control" indicates a lack of control response.

The evidence indicates that the loss of aileron control experienced by the crew was the result of a disconnect in the aileron primary control system between the pilot's control wheel and the aileron boost input quadrant. Specifically, this disconnect occurred in the left wing down cable when the cable connector became completely unscrewed from the forward terminal block of the slack absorber. A discussion of this control system failure is given in succeeding paragraphs.

Measurements of the main actuating cylinder of the aileron boost unit represented a right wing down control movement. Marks made on the inboard closing rib of the right aileron indicated an aileron displacement corresponding to right wing down; however, the pilot's control wheel was positioned for a full left wing down aileron movement. These findings indicate that the pilot was attempting to recover from a right wing down condition, but that the ailerons were not responding.

A previous description of the aileron primary control system showed that between the pilot's and copilot's control wheels and the aileron boost input quadrant, two cables run through a series of pulleys to the boost input quadrant, forming a closed loop; that the pilot's cable is in tension for a right wing down movement and the copilot's cable is in tension for a left wing down movement, and that these cables respond to movement of the control wheels either in the boost-engaged or the boost-disengaged condition. Furthermore, it has been established that if a disconnect or failure in either cable occurs, a loss in aileron control will result. It has also been shown that if a sudden disconnect or failure occurs in the copilot's cable, the rigging tension in the pilot's cable will displace the boost input quadrant, thereby imparting a signal to the aileron boost unit for a right wing down movement.

As previously indicated, examination of the aileron primary control system revealed that the right wing down cable connector which screws into the forward terminal block of the pilot's slack absorber unit was not secured with safety wire and was unscrewed to an engagement of only 0.40 to 0.45 inches (normal engagement, 1.2 to 1.45 inches). This condition can be attributed to either the natural tendency of an unsafetied cable to unwind or that this was the position to which the connector was unscrewed during the aileron boost unit change. The pilot's cable was

still threaded through its pulley bracket guide hole, but the copilot's corresponding left wing down cable, connector, and slack absorber were missing and could not be found. In addition, the copilot's pulley bracket guide hole showed marks of a pronounced indentation, indicating that some object had passed through it in a forward direction. These marks closely matched the shoulder of a swaged cable connector.

The pilot's and the copilot's cables run parallel to each other and pass through their respective guide holes in the pulley bracket. Each guide hole is 0.6 inch in diameter. The slack absorber terminal block is too large to be pulled forward through such a hole and the parted end of a flexible cable is not capable of making an indentation in the guide hole such as was found. The only object capable of making these marks, and which would also permit the missing copilot's cable to pass through the pulley bracket, was the connector on the aft end of the flexible cable which joins the forward terminal block of the slack absorber. Load tests have proved that failure in a cable and swaged connector system first occurs in the flexible cable itself, without any damage whatsoever to cable connectors and other components of the system. Other tests have proved also the natural tendency of a flexible cable to unscrew from its fitting when not secured to it by safety wire. This evidence indicates that the copilot's flexible cable connector completely disengaged from the slack absorber between the time the aircraft started its right turn and the time it crashed.

As previously mentioned, when the copilot's cable is suddenly separated the resulting tension on the right wing down cable imparts an immediate signal to the aileron boost unit for a right wing down control movement. These tests also disclosed that if the forces on the boost quadrant were released, the propensity of the system would be to return the ailerons to neutral in approximately seven seconds, provided no part of the system hangs up or binds. However, the tests involving cable separation further showed a tendency of the cable connectors between the forward flexible cables and the lockclad cables to bind with airframe structure. Because of the mechanical advantage of the system, only a small hang-up force would hold against in-flight airloads and would prevent the aileron boost unit from returning to the neutral position.

In this accident, it is believed that the left wing down cable did separate. With the left wing down cable separated it was not possible for the pilot to apply opposite aileron to bring the right wing up. Then, if the cable connectors did hang up, the ailerons would not have returned to neutral, worsening an already unmanageable situation. Since witnesses observed the bank to the right to increase steadily, and since the right aileron was found in a position of right wing down, there is further reason to conclude that the cable struck in the right wing down position somewhere within the aileron control system. Other recovery techniques such as use of rudder, asymmetrical power, and aileron tabs might have been effective in overcoming the steepening bank, had sufficient altitude been available.

The investigation disclosed that the aileron boost unit on N 137US was changed during two workshifts on July 11 and 12, 1961, approximately 65 days before the accident. A discussion of how this unit was changed and what effect the unit change had on the accident follows. Since this aileron boost unit change was the first such task to be performed by the line maintenance personnel involved, it was important that the maintenance manual prescribing the steps to be followed in changing the unit be followed step by step. Despite its importance, however, the testimony revealed that this was not done. To facilitate removal, cable tension was lessened

by removing safety wire and unscrewing the cable connectors at the forward end of the slack absorbers, as prescribed by the manual. However, when a shift change occurred between the removal and the reinstallation, the mechanics who accomplished the reinstallation performed the task without knowledge of the work accomplished on the unit during the previous shift, and they completely overlooked the extremely important cable rigging instructions prescribed by the manual. As a result, the connectors, unsafetied and unscrewed during the removal, were never tightened and resafetied after reinstallation. The use or non-use of red Unit Inoperative Tags by the maintenance personnel involved could not be clearly established by the testimony, but, if used, it is certainly clear that they were not used properly. The fact that no mechanic called for an inspection of the completed installation was made manifest by the testimony.

Evidence indicates that the amount of supervision devoted to this aileron booster assembly change fell considerably short of meeting the safety minimums desired and expected in a task of this nature. Testimony also established that, although the offices of the foreman and the lead inspector were physically located adjacent to each other, there was a decided lack of coordination between maintenance supervisors and the Inspection Department. Moreover, no inspection was called for by the crew chief who, without studying the manual instructions, performed a cursory inspection of the completed installation and signed the job off as completed. Although several basic managerial controls existed at the time which would have assured the proper completion of this task, the testimony indicates that little attention was given to assure job continuity between shifts and to the use of Unit Inoperative Tags; and that company policy requiring an inspection of the completed installation was not complied with.

Although personnel of the Inspection Department were aware of the fact that the aileron boost unit was being changed, they failed to attach sufficient importance to the Inspection Activity Report entries to assure a timely inspection of the completed installation. Notwithstanding the fact that the boost change was carried on the Inspection Activity Reports throughout two successive workshifts, none of the inspectors on these shifts made any determination as to when the job would be completed. The Lead Inspector on Shift 1, the last shift involved, noted those entries on the two previous shifts' activity reports and saw no entry indicating that an inspection had been made, yet took no action to determine whether or not the installation had been inspected. The testimony indicates that all inspection personnel concerned believed that responsibility for a followup inspection notice rested upon line maintenance and not upon the Inspection Department. At the public hearing there appeared to be differences of opinion on the part of the carrier's maintenance and inspection personnel in their interpretation of the previously mentioned interoffice memorandum of June 21, 1957. These differences concerned whether it was the responsibility of line maintenance supervisors to give notice, or the Inspection Department to follow up, to insure that the aileron boost change was properly inspected upon completion.

The Board believes that this memorandum clearly placed the primary responsibility for followup inspection on the Inspection Department, and that the memorandum and the carrier's maintenance manual, taken together, also made it imperative that maintenance personnel secure an inspection of the completed installation. The Board therefore concludes from the testimony that maintenance and inspection personnel showed an ignorance or disregard of published directives and instructions

A final management control which might have assured proper completion of the

aileron boost change was not complied with when the Shift 1 Crew Chief released the aircraft for flight on July 12, 1961, without the appearance of an inspector's signature on the aircraft log. This Crew Chief had reviewed the log entries and had noted that the aileron boost work was signed off by the Shift 2 mechanics; yet he could not give a satisfactory answer as to why he had released the aircraft for flight without an inspector's signature on the log.

The preponderance of evidence shows that the following chain of events led to, and had a direct bearing on, the destruction of N 137US on September 17, 1961: At, or shortly after, the aircraft began its turn to the right following takeoff from O'Hare Airport, a failure occurred in the aileron primary control system between the boost input quadrant and the control wheel. This failure was caused by a separation of the left wing down cable from the slack absorber on the copilot's side. Failure at this point made it impossible for the crew to decrease the steepening bank or effect a recovery by any means at such a low altitude. In connection with the failure experienced, it was established that two months prior to the accident, during an aileron boost unit change, the cable connectors to the slack absorber terminals were unsafetied and unscrewed, and that these connectors were never tightened and resafetied before the aircraft was released for flight. During the period July 12, 1961, until the accident, it is believed that there occurred a gradual unscrewing of the connector in question until it finally separated from the slack absorber following takeoff on the flight involved.

Mention has already been made of the fact that eight aileron flight control discrepancies were reported by pilots on the logs of N 137US from June 27, to July 11, 1961, the date the aileron booster unit was removed, and that during this time the aircraft was flown on a total of 29 scheduled flights. The aircraft logs recording the corrective actions taken indicate that little effort was made to analyze the cause of these discrepancies and to correct them. This type of operation reflects a casual attitude on the part of maintenance personnel toward a potentially hazardous condition, which was also evident in the replacement of the aileron boost assembly.

The training of Northwest Airlines line maintenance personnel on the Lockheed Electra appeared to have been sporadic and inadequate in scope, particularly with reference to flight control systems. Although the changing of this aileron boost unit provided an excellent opportunity for advantageous use of the existing on-the-job training program, this potential went unrealized.

Probable Cause

The Board determines that the probable cause of this accident was a mechanical failure in the aileron primary control system due to an improper replacement of the aileron boost assembly, resulting in a loss of lateral control of the aircraft at an altitude too low to effect recovery.

BY THE CIVIL AERONAUTICS BOARD:

/s/ ALAN S. BOYD
Chairman

/s/ CHAN GURNEY
Member

/s/ ROBERT T. MURPHY
Vice Chairman

/s/ G. JOSEPH MINETTI
Member

/s/ WHITNEY GILLILLAND
Member

Attachments -

1. Estimated Flightpath Chart
2. Sketch of Aileron Primary Control System
3. Photograph of Pilot's Slack Absorber Unit

S U P P L E M E N T A L D A T A

Investigation and Hearing

The Civil Aeronautics Board was notified of this accident at 0925 on September 17, 1961. Investigators were immediately dispatched to the scene and an investigation was initiated and conducted in accordance with the provisions of Title VII of the Federal Aviation Act of 1958. A public hearing was ordered by the Board and held at the Midway Hotel, Chicago, Illinois, on October 11-12, 1961, and continued at the same location on January 9-11, 1962. In order to obtain the testimony of three witnesses who were unable to attend the public hearings, depositions were taken at Minneapolis, Minnesota, on March 6, 1962.

Air Carrier

Northwest Airlines, Inc., with headquarters in Minneapolis, Minnesota, holds a certificate of public convenience and necessity issued by the Civil Aeronautics Board to engage in the transportation of persons, property and mail. It also possesses a valid air carrier operating certificate issued by the Federal Aviation Agency.

Flight Personnel

Captain Ralph E. Hagstrom, age 50, was employed by Northwest Airlines, Inc., April 11, 1942. He held a valid air transport certificate, No. 158066, multi-engine land, with many type ratings, among which was the Electra aircraft. His last first-class FAA physical examination was taken August 8, 1961, with no waivers. He had a total of 15,898 flying hours, of which 314 were in Electra aircraft.

First Officer Richard L. Anderson, age 33, was employed by the company April 20, 1951. He held a valid air transport certificate, No. 1066954, multi-engine land, with a rating in the DC-4, and was qualified as first officer in Electra aircraft. His last FAA first-class physical examination was taken March 30, 1961, with no waivers. He had a total flying time of 6,643 hours, of which 90 were in Electra aircraft.

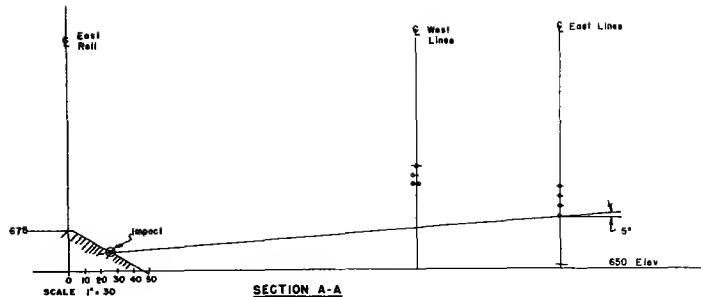
Flight Engineer Wayne H. Fuller, age 34, was employed by the company March 19, 1948. He held flight engineer certificate No. 1304929. His last FAA second-class physical examination was July 14, 1961. He had a total flying time of 3,368 hours, of which 556 were in Electra aircraft.

Stewardess Rosemary Patricia Bilski, age 28, was employed by the company on June 29, 1957. She completed her Electra qualifications on August 19, 1959.

Stewardess Jeanette Ruth McKenzie, age 22, was employed by the company on April 8, 1960, upon completion of her Electra training.

The Aircraft

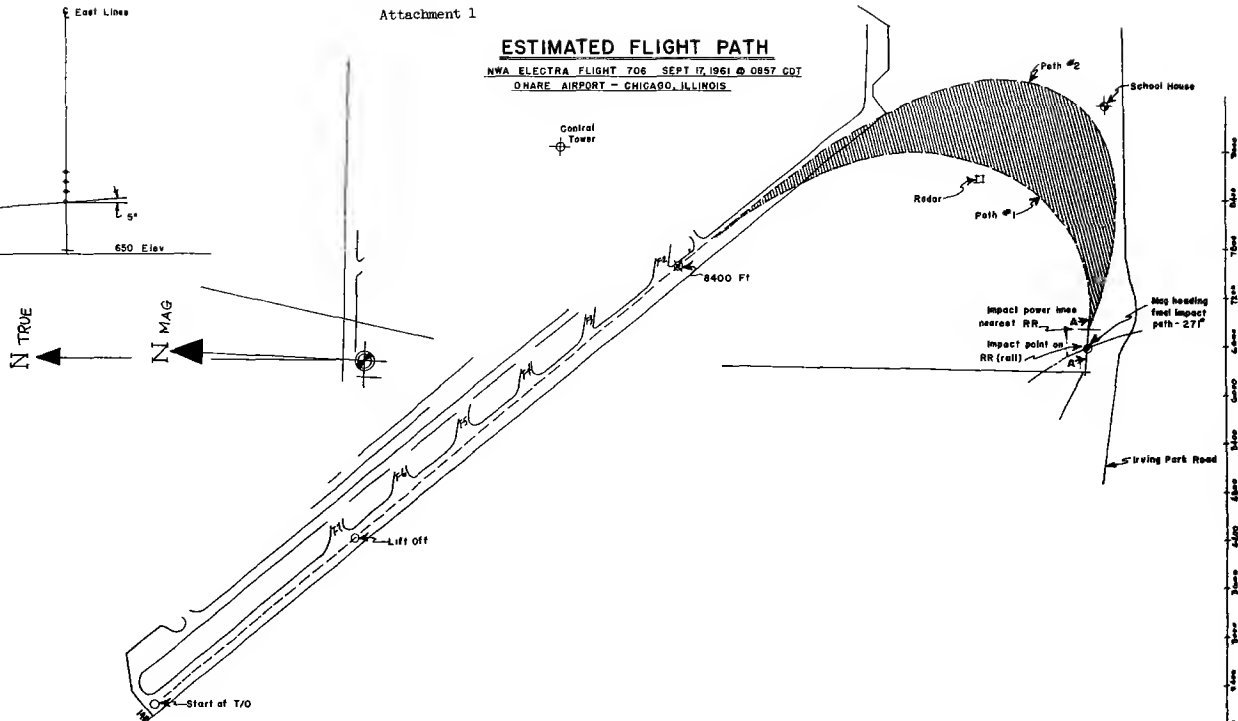
A Lockheed Electra, model L-188C, was manufactured June 14, 1960, serial No. 1142. The Lockheed Electra Action Program (LEAP) was completed January 31, 1961. After its second and final acceptance flight, June 21, 1961, the airplane was delivered to Northwest Airlines on June 22, 1961. The aircraft had a total flying time of 614 hours. It was equipped with four Allison model 501-D13 engines, and four Aero Products propellers, model A 6441FN-606.



Attachment 1

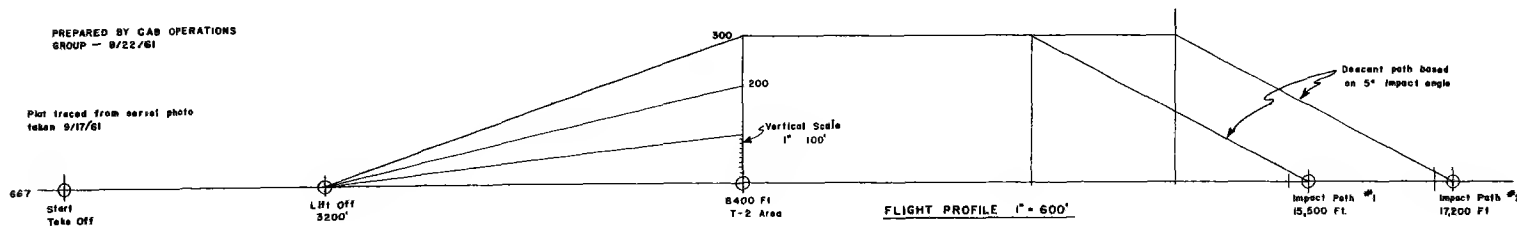
ESTIMATED FLIGHT PATH

NWA ELECTRA FLIGHT 706 SEPT 17, 1961 @ 0857 CDT
O'HARE AIRPORT - CHICAGO, ILLINOIS

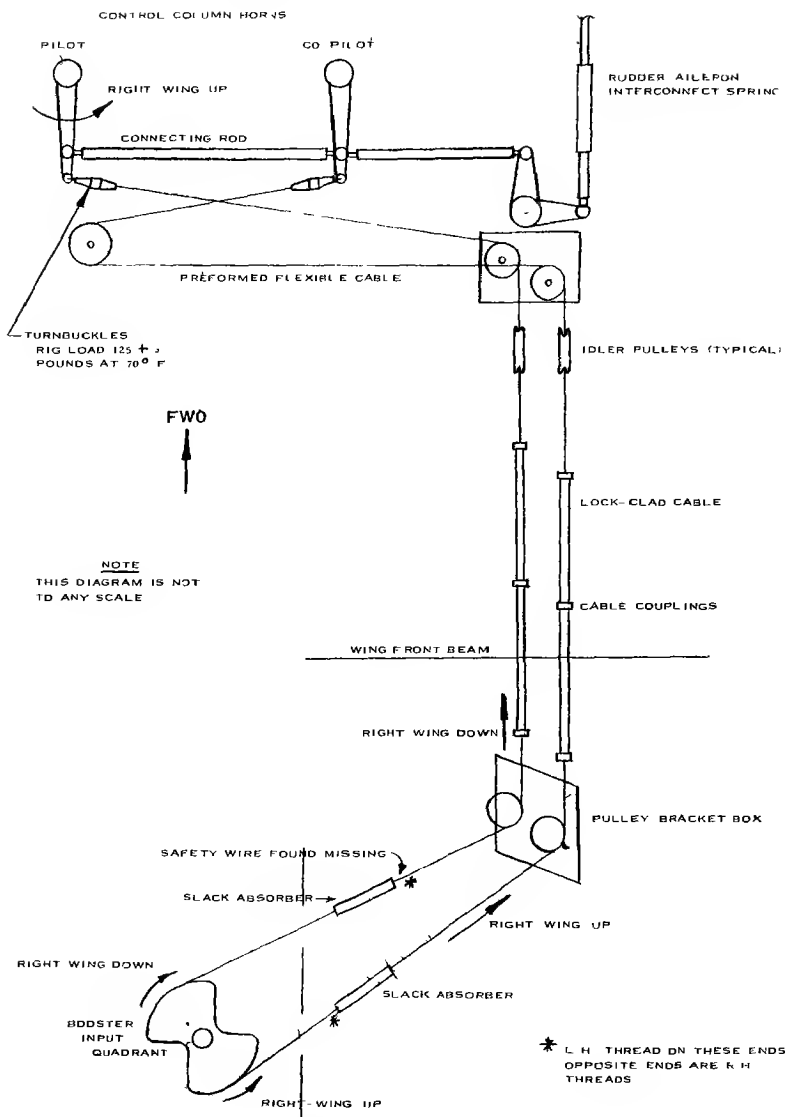


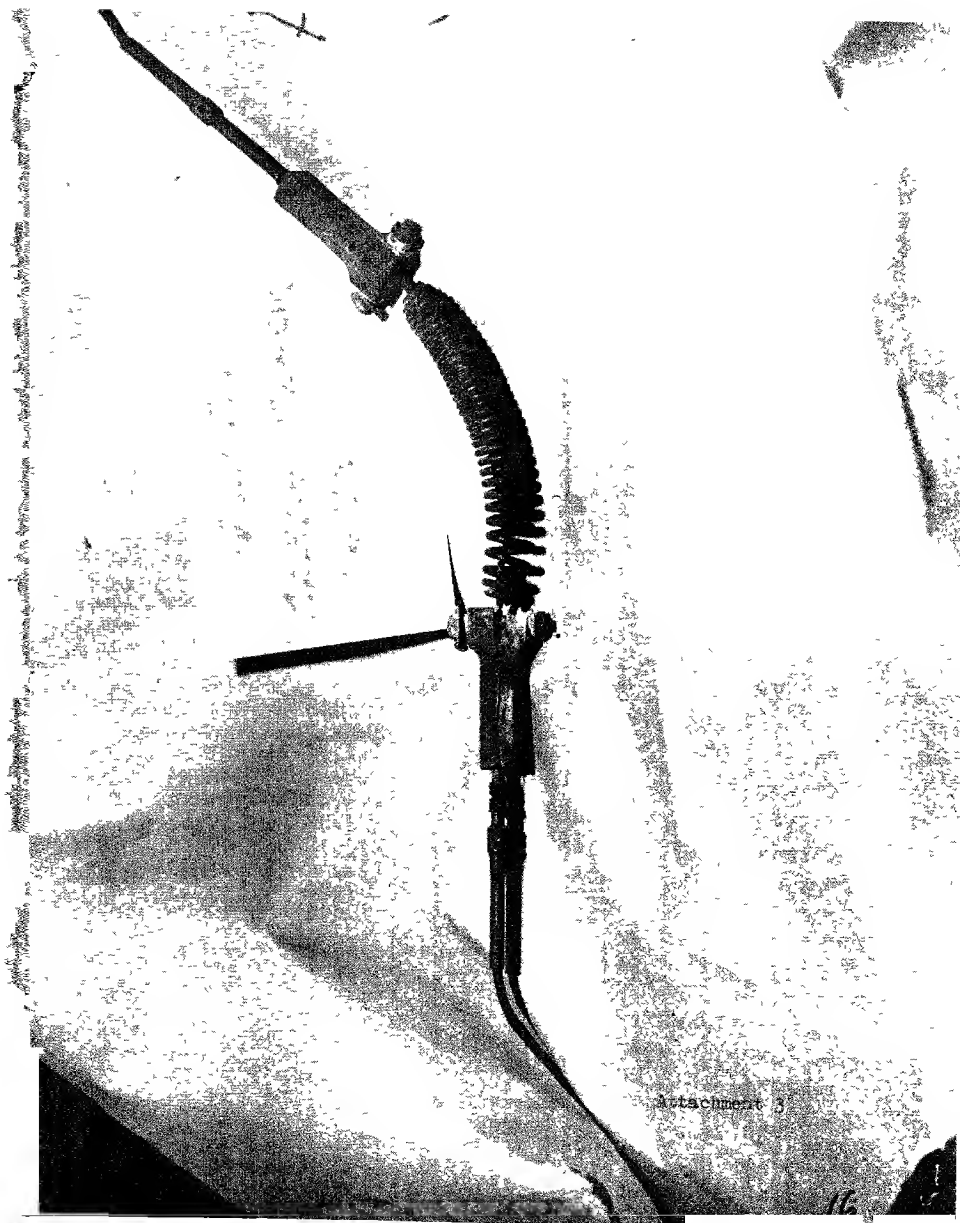
PREPARED BY CAB OPERATIONS
GROUP - 8/22/61

Plot traced from aerial photo
taken 9/17/61



AILERON PRIMARY CONTROL SYSTEM





Attachment 3